

THE INFLUENCE OF COTTON NONCELLULOSIC NATURALLY OCCURRING MATERIALS ON YARN PROCESSING PROPERTIES

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ABSTRACT. Cotton fibers contain naturally occurring noncellulosic materials such as sugars, wax, metals, and other organic species that may significantly affect textile yarn manufacturing efficiency, processing performance, and quality. Chemical and physical tests were conducted on raw cottons from different U.S. growing areas to determine the effect of different concentrations of these materials and fiber frictional properties on rotor and ring spinning performance and yarn properties. Yarn break factors and single yarn strengths were found to increase, and evenness thick and thin places were found to decrease, as levels of ethyl alcohol extractions, the metals potassium and magnesium, and RotorRing friction increased. Yarn strengths decreased and thick and thin places increased in ring spinning as levels of the metal calcium increased. Ring yarn neps increased and rotor yarn neps decreased as alcohol extractions, wax levels, potassium and magnesium content, and fiber to metal friction increased.

Keywords. Break factor, Correlation, Cotton, Evenness, Extraction, Friction, Metal, Noncellulosic, Processing performance, Quality, Ring spinning, Rotor spinning, Strength, Sugar, Wax.

Noncellulosic materials on raw cottons can adversely affect processing efficiency, yarn physical properties, and end product quality. Non-fibrous materials (e.g., plant leaf trash, seed coat fragments, oils, man-induced contaminants, and other naturally occurring materials) resulting from the growing, harvesting, and ginning processes may also be present. Excessive levels of trash and seed coat fragments are removed in the opening, cleaning, and carding processes and therefore do not usually create problems in yarn manufacturing. Oils and man-induced contamination generally represent a very small portion of the overall annual cotton crop. In such cases, special handling techniques are required. The combined concentrations of the remaining noncellulosic materials on the fiber can easily exceed 20 g/kg, or 2.0% of the fiber weight. They are generally considered to be surface related and include sugars, wax, metals, and other organic species that may affect fiber performance in textile processing (Rollins, 1965). Previous studies have documented the effects of sugars (both natural and insect-induced), seed coat fragments, trash, and oil contamination on processing (Carter, 1990; Perkins, 1971; Perkins and Bragg, 1977). There is, however, limited information available on the effects of fiber wax, residual metals, and other solvent-extractable noncellulosic materials on yarn quality.

Wax generally serves as a fiber lubricant and anti-static agent in textile processing. Natural cotton wax concentrations may vary from 2.0 to 10 g/kg (0.2% to 1.0%) depending

upon a number of factors, including fiber micronaire, length of growing season, fiber maturity, and field weathering (Perkins, 1971). Potassium, the most abundant metal on cottons, and other metals are important nutrients for the natural development of the fiber. Combined potassium, calcium, magnesium, and sodium normally account for 900 to 950 g/kg (90% to 95%) of the metals on cotton. Trace amounts of other metals such as aluminum, iron, copper, manganese, and zinc have also been found to be present (Heinzelman and O'Connor, 1950; Brushwood and Perkins, 1992; Brushwood and Perkins, 1994).

The amount of materials removed from fiber by extraction with ethyl alcohol is considered to be a very good indicator of the noncellulosic content. Residues contain surface wax, sugar, other organic hydrocarbons, and portions of easily removed light metals, such as potassium and sodium. However, the ethyl alcohol extraction process does not remove most of the calcium, magnesium, and heavy metals on the fiber.

Cotton fiber friction (cohesion) is defined as the energy required in separating a fiber or fibers from each other or an assembly. This depends on fiber "consistency," which is defined by a number of properties, including staple length, surface roughness, and fiber entanglement. Hence, fiber frictional properties can be highly related to yarn processing performance and quality.

This research project was undertaken to: (1) measure levels of noncellulosic materials and frictional properties on a series of U.S. grown raw cottons representing several different varieties and growing areas, and (2) determine possible relationships between the fiber frictional properties and concentrations of these materials and yarn spinning performance. This report is a summary of the correlations found.

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EXPERIMENTAL DESIGN

Twenty-one domestically grown and commercially ginned cottons from the 1991 Leading Variety Study were spun into rotor and ring yarns. These cottons included nine different varieties and five general growing areas ranging from the Southeast (South Carolina and Georgia) to the West (California and Arizona). Fiber micronaire ranged from a low of 3.4 for a High Plains of Texas to 4.9 for a Tennessee grown cotton.

Raw fiber samples were conditioned in the laboratory for a minimum of three weeks before moisture, sugar, wax, and alcohol extractable determinations were conducted. Triplicate fiber moisture contents (ASTM method D2495–01) for the cottons ranged from 66.6 to 72.8 g/kg (6.66% to 7.28% w.b.) with no significant difference seen between variety and growing location. The standard deviation for this moisture determination was 0.10% w.b. Individual fiber moisture contents were used in the determination of the concentrations of sugars, wax, metals, and ethyl alcohol extractable materials.

Wax and total surface material extractions were conducted using six-hour Soxhlet extractions of 2.5 g samples (1–1–1 trichloroethane solvent for wax and 950 g/kg (95%) ethyl alcohol for total surface materials). Resultant wax and alcohol extractable contents were averaged from a total of 24 extractions per cotton. The standard deviation for alcohol and wax extractions was 30 g/kg (3%) of the amount determined. Sugars (in triplicate) were determined by the USDA potassium ferricyanide (Perkins, 1971) reducing sugar test. The standard deviation was 100 g/kg (10%). Metal contents, at least duplicate determinations of triplicate samples, were determined by atomic absorption (AA) spectroscopy using a Buck 200 instrument (Buck Scientific, East Norwalk, Conn.) as specified in a previous study (Brushwood and Perkins, 1994). The standard deviation for determination of metals was 50 g/kg (5%). Average ash residues determined (at least triplicate determinations/sample) in preparing solutions for metals by AA analysis had a standard deviation of 40 g/kg (4%).

Fiber RotorRing friction tests were conducted by the Institute of Textile Technology (ITT) Laboratory in Charlottesville, Virginia. Fiber-to-metal (f/m) and fiber-to-fiber (f/f) friction values were reported in the energy units of joules (J) (Ghosh et al., 1992). At least four replicate measurements per test were conducted per cotton and the results averaged.

All cottons were processed into rotor yarn (Ne 10/1, 22/1, and 30/1) and ring yarn (Ne 22/1, 36/1, and 50/1) on standard textile processing equipment at the USDA-ARS Cotton Quality Research Station in Clemson, South Carolina. Production test data for these fibers include yarn skein break factor, which is a measure of the yarn's resistance to rupture, elongation, single yarn strength, Uster evenness tests, opening/carding wastes, and ring spinning ends down, which is a measure of interruptions in the spinning process.

The significance of averages for the data was determined by statistical variance of mean and t-tests. Area of growth correlation coefficients were determined by using the mean values for each growing area. For example, five points were used to determine the area of growth correlation between fiber alcohol extractions and yarn skein break factor.

Table 1. Average fiber micronaires, reducing sugar, wax, alcohol extractables, and ash residues for the 1991 Leading Variety cottons.

Location	Micronaire	Reducing Sugars (g/kg)	Wax (g/kg)	Alcohol Extractables (g/kg)	Ash (g/kg)
Central					
Arkansas	4.4	2.3	4.4	13.1	12.7
Missouri	4.3	3.3	4.3	11.1	13.7
Tennessee 1	4.7	2.6	3.7	12.0	12.7
Tennessee 2	4.9	2.8	3.4	12.0	13.7
Average	4.6	2.8	4.0	12.1	13.2
Standard error	0.14	0.2	0.2	0.4	0.3
Midsouth					
Louisiana	3.9	3.0	4.2	13.6	11.0
Mississippi 1	4.6	2.3	3.8	12.7	10.0
Mississippi 2	4.1	2.1	4.3	13.4	12.9
Mississippi 3	4.5	4.5	4.4	14.1	14.8
Average	4.3	3.0	4.2	13.5	12.2
Standard error	0.17	0.5	0.1	0.3	1.0
Southeast					
South Carolina	4.0	2.4	4.3	16.7	12.5
Georgia	4.5	2.6	4.5	13.9	12.0
Average	4.3	2.5	4.4	15.3	12.3
Standard error	0.25	0.1	0.1	1.4	0.3
Southwest					
Texas 1	3.8	2.1	5.2	12.9	14.8
Texas 2	3.9	2.3	3.9	13.7	13.2
Texas 3	4.4	2.9	4.1	12.2	12.7
Texas 4	3.4	6.1	4.5	17.5	15.3
Texas 5	4.0	4.1	4.7	18.1	13.0
Average	3.9	3.5	4.5	14.9	13.8
Standard error	0.16	0.7	0.2	1.2	0.5
Western					
Arizona	4.3	3.7	4.5	16.6	13.8
California 1	4.8	4.2	3.9	17.0	15.2
California 2	3.8	6.1	4.9	21.1	21.1
California 3	4.0	4.8	4.1	20.8	16.4
California 4	4.2	5.1	4.7	20.6	18.2
California 5	4.0	4.2	4.4	18.3	15.7
Average	4.2	4.7	4.4	19.1	16.7
Standard error	0.14	0.3	0.2	0.8	1.0

RESULTS AND DISCUSSION

Relationships between the fiber noncellulosic material content and yarn processing performance were determined for all 21 cottons as well as by growing area. Since it has been previously demonstrated that area of growth may have a significant effect on fiber noncellulosic content (Brushwood and Perkins, 1994), five growing locations were chosen for these cottons. There were six cottons from the West (California and Arizona), five from the High Plains of Texas, four from the central U.S. (Arkansas, Tennessee, and Missouri), four from the Midsouth (Louisiana and Mississippi), and two from the Southeast (South Carolina and Georgia). A previous study documenting relationships found between raw cotton noncellulosic content and fiber physical properties using area of growth averages involving these same cottons is reported by Brushwood (2003). Although, in some cases, there are no real significant average differences

determined between levels of fiber noncellulosic materials and specific growing areas, relationships using area of growth are included here strictly to illustrate that location effects should be considered. For example, growing area has an effect on fiber micronaire. When averaged by area, micronaire ranged from a low of 3.90 for Southwestern (High Plains Texas) cottons to a high of 4.60 for Central (Tennessee, Missouri, and Arkansas) cottons (table 1). High Volume Instrument (HVI) fiber strengths ranged from a low of 239 mN/tex (single Texas cotton) to 299 mN/tex for the Arizona cotton. The same two fibers had the low and high mean fiber lengths at 21.3 mm (0.84 in.) and 26.4 mm (1.04 in.), respectively. Growing area fiber mean length averages ranged from a low of 22.9 mm (0.90 in.) for Southwestern (Texas) to 26.2 mm (1.03 in.) for Western cottons.

CHEMICAL ANALYSIS

Table 1 lists individual fiber and growing area averages for fiber micronaire, reducing sugars, wax, total alcohol extractables, and ash residues determined for the 21 cottons. Reducing sugars ranged from 2.1 to 6.1 g/kg (0.21% to 0.61%). Higher averages were found on Western (4.7 g/kg) and Southwestern (3.5 g/kg) grown cottons. Wax content, which is highly related to micronaire (Perkins, 1971), ranged from 3.4 g/kg to 5.2 g/kg (0.34% to 0.52%). By growing area, the five Southwestern cottons averaged 4.5 g/kg (0.45%) wax content and the lowest overall average micronaire of 3.90. The overall coefficient of simple correlation between wax content and fiber micronaire for these samples was $r = -0.62$. As fiber micronaire decreased, wax content increased. No significant differences in either sugar or wax concentration were seen between varieties.

Alcohol extractable materials ranged from 11.1 to 21.1 g/kg (1.11% to 2.11%), with Western cottons averaging almost 250 g/kg (25%) higher than the other locations. In general, those cottons yielding higher levels of alcohol extractions correlated well with increases in fiber HVI strength and reducing sugar levels. For the 21 cottons, the correlation between alcohol extractions and HVI strength was $r = 0.59$, and the correlation between alcohol extractions and reducing sugar content was $r = 0.78$. Individual ash residue, produced prior to determination of metals, ranged from 10.0 to 21.1 g/kg (1.00% to 2.11%). Western cottons averaged a high of 16.7 g/kg (1.67%) and Midsouth cottons a low of 12.2 g/kg (1.22%). A positive correlation was found between alcohol extractables and ash residues ($r = 0.74$).

METALS

Average individual fiber and growing area concentrations of potassium, calcium, and magnesium are listed in table 2. Potassium concentrations ranged from just below 3.0 g/kg (2960 ppm) to nearly 7.0 g/kg (6960 ppm), calcium from 575 to 1225 ppm, and magnesium from 310 to 740 ppm for all 21 samples. Western cottons averaged about 250 g/kg (25%) more potassium than other growing locations, and Texas (Southwestern) cottons averaged about 200 g/kg (20%) more calcium content than other locations. Total major light metal contents (combined potassium, calcium, and magnesium concentrations) ranged from a low of 3900 ppm (based on fiber wet basis) to a high of 8000 ppm.

Table 2. Average light metal contents and RotorRing friction measurements for the 1991 Leading Variety cottons.

Location	Light Metals			Fiber Friction (J)	
	K (ppm)	Ca (ppm)	Mg (ppm)	Fiber-to-metal	Fiber-to-fiber
Central					
Arkansas	3910	690	476	9352	19294
Missouri	3650	1130	565	10928	17441
Tennessee 1	4400	860	540	9339	17786
Tennessee 2	3330	770	490	7763	18298
Average	3823	863	518	9345	18205
Standard error	226	96	58	646	403
Midsouth					
Louisiana	3510	650	445	8439	17453
Mississippi 1	2960	620	310	8442	22016
Mississippi 2	3780	840	390	8439	17453
Mississippi 3	4260	960	610	9360	20873
Average	3628	768	439	8670	19449
Standard error	35	81	63	230	1176
Southeast					
South Carolina	4340	575	465	8238	19980
Georgia	4410	690	420	12282	20917
Average	4375	633	443	10260	20449
Standard error	290	58	23	2022	469
Southwest					
Texas 1	3930	1175	580	10699	20767
Texas 2	3880	1225	395	15861	17889
Texas 3	3280	840	355	10976	19991
Texas 4	4980	1215	535	9710	17266
Texas 5	4480	780	580	12546	15506
Average	4110	1047	489	11958	18284
Standard error	289	98	48	1077	948
Western					
Arizona	3950	610	415	9573	22686
California 1	4700	695	455	12907	21273
California 2	6960	1030	740	10915	19316
California 3	4970	900	725	13393	22586
California 4	6470	860	685	13293	21797
California 5	5510	600	610	9686	24097
Average	5427	783	605	11628	21959
Standard error	461	71	57	730	658

FIBER-FRICTION MEASUREMENTS

RotorRing f/m and f/f friction averages ranged from 7760 to 15860 J for f/m and 15500 to 24100 J for f/f measurements. In general, f/f friction measurements were about twice those of the f/m friction (table 2). Cottons originating from the Western and Southwestern growing areas had higher f/m frictional properties. RotorRing f/f frictions area of growth averages ranged from 18205 J (Central growing area) to a high of 21960 J for Western grown cottons.

SPINNING PERFORMANCE DATA

Yarn skein break factor and elongation results for each of the three different size yarns produced in rotor and ring spinning are listed in table 3. In general, ring spun 22s count yarns averaged higher break factors and lower elongation percentages than corresponding rotor spun yarns. Western cottons (California and Arizona) averaged about 150 g/kg (15%) higher break factors than any other growing area.

Single yarn strength test results for each spinning system are shown in table 4. As with break factor measurements, single yarn strengths were consistently higher for cottons

Table 3. Yarn skein break factors and elongations for different yarn sizes.

Location	Rotor						Ring					
	Break Factor			Elongation (%)			Break Factor			Elongation (%)		
	10s	22s	30s	10s	22s	30s	22s	36s	50s	22s	30s	50s
Central												
Arkansas	2019	1663	1532	7.5	6.2	6.0	1995	1828	1570	4.4	4.5	5.0
Missouri	2169	1686	1542	6.4	5.9	5.5	2039	1725	1440	6.4	5.1	4.9
Tennessee 1	2136	1767	1599	7.0	6.5	5.7	2036	1814	1456	5.9	5.3	4.8
Tennessee 2	1979	1719	1507	6.3	5.8	5.5	1882	1651	1332	5.5	4.7	4.7
Average	2076	1709	1545	6.8	6.1	5.7	1988	1755	1450	5.6	4.9	5.0
Midsouth												
Louisiana	2186	1885	1706	7.5	6.5	6.0	2175	2041	1769	6.0	6.2	5.5
Mississippi 1	2105	1779	1575	6.6	6.0	5.5	1939	1739	1523	6.2	5.1	5.0
Mississippi 2	2427	1988	1800	7.0	5.9	6.0	2265	2094	1778	6.1	5.8	5.0
Mississippi 3	2390	1968	1739	7.0	6.7	6.2	2265	2136	1852	6.5	5.8	5.3
Average	2277	1905	1705	7.0	6.3	5.9	2161	2003	1731	6.2	5.7	5.2
Southeast												
South Carolina	2378	2081	1873	7.7	6.0	5.7	2330	2302	1887	5.8	5.5	4.5
Georgia	2217	1896	1696	6.1	5.8	5.3	2154	1965	1641	5.3	4.5	4.5
Average	2298	1989	1785	6.9	5.9	5.5	2242	2134	1764	5.6	5.0	4.5
Southwest												
Texas 1	2415	2128	1905	7.4	6.7	6.0	2239	2043	1743	6.3	5.5	5.0
Texas 2	2525	2157	1978	7.0	6.0	5.5	2386	2290	1950	4.7	5.5	4.4
Texas 3	2173	1854	1574	6.8	6.3	5.5	2025	1852	1555	6.0	5.0	4.5
Texas 4	2118	1786	1598	7.8	6.5	6.5	2001	1714	1663	6.5	5.5	5.8
Texas 5	2173	1787	1619	7.8	6.7	6.5	1982	1717	1469	6.6	5.7	5.0
Average	2281	1942	1735	7.4	6.4	6.0	2127	1923	1676	6.0	5.3	4.9
Western												
Arizona	2467	2112	1923	7.2	6.5	6.2	2561	2329	2032	6.5	5.8	5.3
California 1	2398	1993	1737	6.5	5.7	5.4	2281	2114	1719	5.8	5.0	4.3
California 2	2557	2088	1889	7.5	6.5	6.3	2450	2278	2081	6.4	6.2	5.7
California 3	2699	2256	2050	7.3	6.5	6.2	2717	2525	2222	6.0	5.2	4.9
California 4	2651	2385	2086	7.1	6.3	6.6	2762	2648	2451	6.3	5.5	5.7
California 5	2795	2520	2272	7.5	6.8	6.2	2981	2820	2622	6.8	6.0	5.9
Average	2595	2226	1993	7.2	6.4	6.2	2625	2452	2188	6.3	5.6	5.3

originating from the Western states. Ring 22s count single yarn strength tests averaged 250 g/kg (25%) higher than the 22s rotor yarn. Fiber HVI strength measurements for all 21 cottons were highly related to the yarn break factor and single yarn strength measurements. HVI strength had $r = 0.81$ and $r = 0.75$ correlations with rotor and ring break factors, respectively. The correlations between HVI strength and yarn single end strength were $r = 0.80$ for rotor and $r = 0.76$ for ring samples.

Table 5 is a summary of Uster yarn evenness tests for thick and thin places and nep counts for both spinning systems. Thick and thin places measurements and neps listed are the averages of the combined 10s, 22s, and 30s rotor yarn and 22s, 36s, and 50s ring yarn measurements for each yarn. Southwestern (Texas) cottons averaged at least 100 g/kg (10%) more ring thick and thin place measurements than other growing areas. Western cottons tended to have the lowest number of thick and thin places for both spinning systems. For the ring yarn, neps/914 m (neps/1000 yd) were highest in Western cottons and lowest in Central cottons. Rotor yarn neps were highest in the Southeast and lowest in Southwestern cottons.

Ring spinning ends down and opening/carding waste averages are listed in table 6. Southwestern cottons averaged about 500 g/kg (50%) more ends down than any other growing area. Opening/carding waste ranged from a low of 60.5 g/kg (Arkansas) to a high of 86.7 g/kg (Texas 5).

RELATIONSHIPS BETWEEN FIBER SUGAR, WAX, ALCOHOL EXTRACTABLES, ASH RESIDUES, AND PROCESSING PROPERTIES

Table 7 is a summary of the average coefficient of simple correlations (r values) between the reducing sugar, wax, alcohol extractables, and fiber ash residue and the yarn skein break factor and elongation, single yarn strength, and Uster yarn evenness measurements for ring and rotor yarns. Correlations for the 21 cottons ($n = 21$) and by growing location ($n = 5$) are given. As fiber alcohol extractions, reducing sugar, wax, and ash residue increased, yarn skein break factor, single yarn strength, and ring spinning neps also tended to increase. Figures 1 and 2 show the relationships between alcohol extractables and both yarn skein break factor and single yarn strengths for rotor and ring spun yarns. Correlations were $r = 0.65$ for rotor yarn skein break factor, $r = 0.68$ for the ring skein break factor, $r = 0.61$ for rotor single yarn strength, and $r = 0.65$ for ring single yarn strength. The same correlations, when determined by growing location, were all $r = 0.96$ or better. Uster evenness thick and thin places and rotor neps tended to decrease. There was a much better defined correlation for rotor than ring spun yarns. For example, the rotor thick place correlation with alcohol extractables was $r = -0.67$, and the corresponding ring thick place correlation was $r = -0.36$. As fiber wax concentrations increased, rotor yarn thick places ($r = -0.63$) and thin places ($r = -0.56$) decreased (fig. 3).

Table 4. Single yarn strength measurements for rotor and ring spun yarns.

Location	Rotor (mN/tex)			Ring (mN/tex)		
	10s	22s	30s	22s	36s	50s
Central						
Arkansas	119	106	99	131	113	113
Missouri	126	104	99	131	119	100
Tennessee 1	119	110	98	141	117	104
Tennessee 2	122	97	96	118	108	94
Average	122	104	98	130	114	103
Midsouth						
Louisiana	129	114	107	142	123	119
Mississippi 1	126	108	102	134	122	118
Mississippi 2	139	126	114	145	129	124
Mississippi 3	134	114	106	145	136	130
Average	132	116	107	142	128	123
Southeast						
South Carolina	142	126	111	153	138	130
Georgia	132	109	107	148	127	115
Average	137	118	109	151	133	123
Southwest						
Texas 1	138	125	122	149	143	122
Texas 2	152	128	115	154	142	125
Texas 3	130	115	101	135	121	104
Texas 4	120	100	99	135	114	98
Texas 5	130	110	103	130	125	103
Average	134	116	108	141	129	110
Western						
Arizona	142	123	116	163	149	128
California 1	140	114	105	152	129	127
California 2	144	128	119	148	145	135
California 3	153	134	125	169	167	129
California 4	152	138	132	183	173	160
California 5	162	145	135	188	177	167
Average	149	130	122	167	157	141

FIBER LIGHT METAL CONTENTS AND FRICTION MEASUREMENTS

Highly positive correlations were found between fiber ash residues and the combined total potassium, calcium, and magnesium content ($r = 0.94$). These metals, on average, accounted for about 410 g/kg (41%) of total ash residues. Correlations between yarn processing performance and properties and the individual and combined potassium, calcium, and magnesium contents of the fibers and Rotor-Ring friction measurements are shown in table 8. Increases in the levels of the metals potassium and magnesium correlated with increases in yarn skein break factor and single yarn strength. Correlations were $r = 0.60$ and $r = 0.63$ for the potassium/skein break factor relationship for rotor and ring spun yarns, respectively (fig. 4). The correlations between the potassium content and the single yarn strength measurements were $r = 0.61$ for rotor and $r = 0.62$ for ring yarns (fig. 5). Increasing levels of potassium and magnesium also tended to be related to reductions in Uster yarn evenness thick and thin places (table 8). Conversely, increasing levels of the metal calcium correlated with increasing levels of ring spun yarn Uster evenness thick and thin places and decreases in yarn break factor and single yarn strength.

As RotorRing friction increased, yarn strengths also increased. The RotorRing fiber-to-fiber (f/f) measurement exhibited slightly more positive correlations with skein break

Table 5. Uster evenness yarn thick and thin place and nep measurements of processed yarns.

Location	Rotor			Ring		
	Thick Places	Thin Places	Neps/914 m	Thick Places	Thin Places	Neps/914 m
Central						
Arkansas	83	56	21	2248	1095	766
Missouri	72	32	23	2432	1269	798
Tennessee 1	111	70	33	2882	1228	643
Tennessee 2	104	83	31	2602	1683	647
Average	93	60	27	2541	1319	714
Midsouth						
Louisiana	64	41	33	2258	1109	888
Mississippi 1	83	33	24	2926	1684	977
Mississippi 2	70	56	51	2236	914	742
Mississippi 3	72	40	12	1786	730	544
Average	72	43	30	2302	1109	788
Southeastern						
South Carolina	67	31	32	2353	1193	891
Georgia	48	60	50	2405	1298	783
Average	58	46	41	2379	1246	837
Southwestern						
Texas 1	26	12	11	2798	1647	877
Texas 2	59	22	26	2625	1380	921
Texas 3	72	32	23	2432	1269	798
Texas 4	57	23	25	3147	2434	1128
Texas 5	48	28	14	2771	1680	978
Average	52	23	20	2755	1682	940
Western						
Arizona	73	41	18	2233	1014	926
California 1	52	26	13	2507	1146	864
California 2	43	17	27	2421	983	1410
California 3	39	23	17	1969	681	944
California 4	48	12	29	1698	503	1084
California 5	46	14	26	1381	384	792
Average	50	22	22	2035	785	1003

factor and single yarn strength than those determined for fiber-to-metal (f/m) frictions. In addition, fiber-to-fiber (f/f) correlations with ring spun yarns were more positive than those with rotor spun yarns. The correlation between f/f friction and ring spun single yarn strength ($r = 0.70$) is shown in figure 6. A slightly lower correlation ($r = 0.53$) was found between the same friction measurement and the rotor single yarn strengths. The above correlations, determined using growing area averages, were all $r = 0.90$ or better (table 8). There was a tendency for ring yarn Uster neps to increase and rotor yarn Uster neps to decrease as the metals potassium and magnesium and f/m friction increased.

ENDS DOWN AND OPENING/CARDING WASTE

Ring spinning ends down/914 m (ends down/1000 yd) (table 6) positively correlated with ring yarn thin places ($r = 0.63$) and thick places ($r = 0.54$) measurements. As opening and carding wastes decreased, yarn skein break factor and single yarn strength (table 3) tended to increase. For example, the correlations between rotor and ring single yarn strengths and opening and carding wastes were $r = -0.57$ and $r = -0.63$, respectively. In addition, increases in opening and carding waste tended to correlate with increases in the fiber calcium content ($r = 0.31$).

Table 6. Ends down and waste during processing.

Location	Ring Ends Down/1000 h	Opening/Carding Waste (g/kg)
Central		
Arkansas	21.4	60.5
Missouri	96.6	82.3
Tennessee 1	122.8	78.6
Tennessee 2	250.9	77.5
Average	122.9	74.7
Midsouth		
Louisiana	35.7	69.9
Mississippi 1	47.1	79.6
Mississippi 2	27.1	77.3
Mississippi 3	114.1	64.1
Average	56.0	72.7
Southeastern		
South Carolina	19.4	57.8
Georgia	223.2	74.5
Average	121.3	66.2
Southwestern		
Texas 1	65.2	66.0
Texas 2	200.1	77.3
Texas 3	364.3	71.2
Texas 4	268.8	85.2
Texas 5	87.6	86.7
Average	197.2	77.3
Western		
Arizona	78.4	68.4
California 1	29.6	82.8
California 2	34.8	65.3
California 3	13.6	59.4
California 4	53.2	70.8
California 5	45.7	47.6
Average	42.6	65.7

SUMMARY AND CONCLUSIONS

A series of domestically grown cottons consisting of nine varieties and five growing areas were analyzed for reducing sugars, wax, total surface extractables, fiber ash residue, light metal contents, and frictional properties. Determined values were subsequently correlated to both rotor and ring spinning performance data. No significant varietal effects on these measurements were detected.

Rotor and ring yarn break factor and single yarn strength measurements for all 21 cottons increased, and evenness thick and thin places decreased, as the amount of ethyl alcohol extractable materials removed from the fiber increased. Likewise, yarn break factor and single yarn strength increased and evenness thick and thin places decreased as the levels of sugar, wax, and ash residues increased. Neps in rotor spun yarn decreased and neps in ring spun yarn tended to increase as extractables and ash residues increased.

Increasing levels of the metals potassium and magnesium correlated with increasing rotor and ring spun yarn skein break factors, rotor and ring spun yarn single yarn strengths, and ring spun Uster neps. Evenness thick and thin places and rotor neps decreased. Conversely, increasing levels of calcium on the fiber correlated with decreases in ring spun yarn break factors and single yarn strengths and increases in Uster ring yarn evenness thick and thin places. Ring spun yarn nep count increased and rotor spun yarn nep count decreased as the light metal content (K + Ca + Mg) increased.

RotorRing friction measurements were positively related to ethyl alcohol extractables and residual ash, and therefore positively related to yarn strength measurements. Rotor spun Uster yarn evenness thick and thin places and neps decreased as f/m friction increased. Evenness thick and thin places decreased in both spinning systems as f/f friction increased.

The amount of ethyl alcohol extractable materials removed from cotton fibers may be used as a general predictor of the influence of noncellulosic materials on raw cotton properties, their performance in spinning, and yarn quality. However, the contributions of individual constituents (like sugar, wax, and the presence of specific metals) are also important factors to consider. For example, increasing fiber and yarn strength measurements and decreasing Uster yarn evenness thick and thin places tend to correlate with increasing levels of the metals potassium and magnesium on the fiber. The opposite effect is seen as the fiber calcium content increases.

This study consisted of a limited collection of U.S. grown cottons that were spun by both rotor and ring spinning systems to produce different size yarns. It is clear, from these small samplings, that naturally occurring noncellulosic materials on cottons can have a significant impact on yarn properties, processing efficiency, and end product quality. Additional research with a larger variety of cottons from different growing locations would be a worthwhile expansion of this study.

Table 7. Correlation coefficients between surface extractables and ash residues, and yarn spin performance data.

	Skein				Single Yarn		Uster					
	Break Factor		Elongation		Strength		Thick Places		Thin Places		Neps	
	Rotor	Ring	Rotor	Ring	Rotor	Ring	Rotor	Ring	Rotor	Ring	Rotor	Ring
Reducing sugars												
Individual samples (<i>n</i> = 21)	0.32	0.38	0.52	0.48	0.25	0.33	-0.39	-0.18	-0.47	-0.14	-0.38	0.54
Area of growth (<i>n</i> = 5)	0.80	0.78	0.81	0.66	0.80	0.75	-0.60	-0.49	-0.69	-0.54	-0.78	0.86
Wax												
Individual samples (<i>n</i> = 21)	0.35	0.31	0.63	0.56	0.32	0.35	-0.63	-0.07	-0.56	-0.09	-0.26	0.43
Area of growth (<i>n</i> = 5)	0.74	0.62	0.63	-0.15	0.66	0.60	-0.97	0.00	-0.94	-0.10	-0.65	0.80
Alcohol extractables												
Individual samples (<i>n</i> = 21)	0.65	0.68	0.58	0.38	0.61	0.65	-0.67	-0.36	-0.63	-0.40	-0.24	0.56
Area of growth (<i>n</i> = 5)	0.98	0.96	0.52	0.23	0.98	0.96	-0.88	-0.61	-0.77	-0.65	-0.23	0.86
Ash residues												
Individual samples (<i>n</i> = 21)	0.57	0.57	0.43	0.39	0.57	0.57	-0.47	-0.33	-0.48	-0.37	-0.18	0.53
Area of growth (<i>n</i> = 5)	0.73	0.73	0.63	0.52	0.90	0.74	-0.50	-0.52	-0.52	-0.54	-0.67	0.83

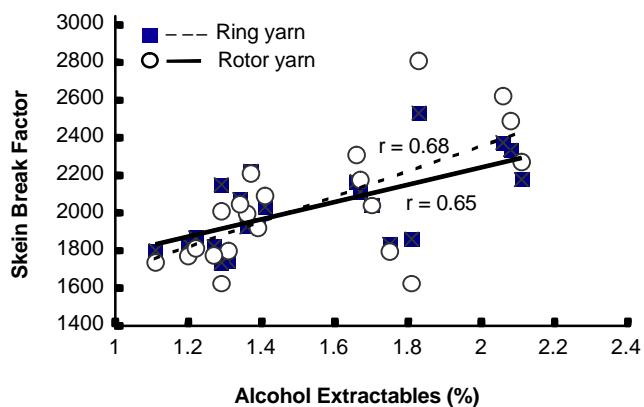


Figure 1. Relationship between ethyl alcohol extractables and yarn skein break factor.

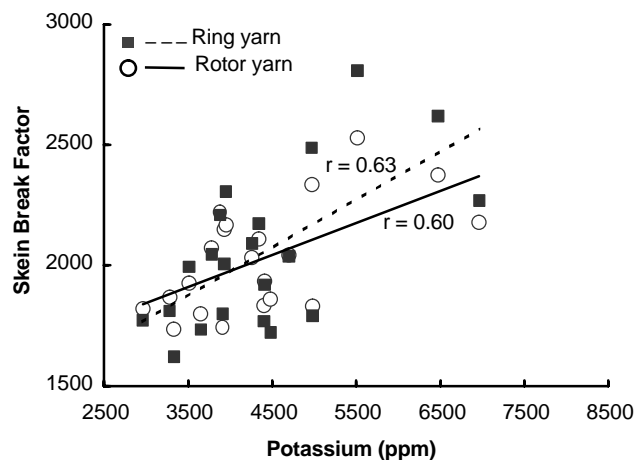


Figure 4. Relationship between the fiber potassium content and yarn skein break factor.

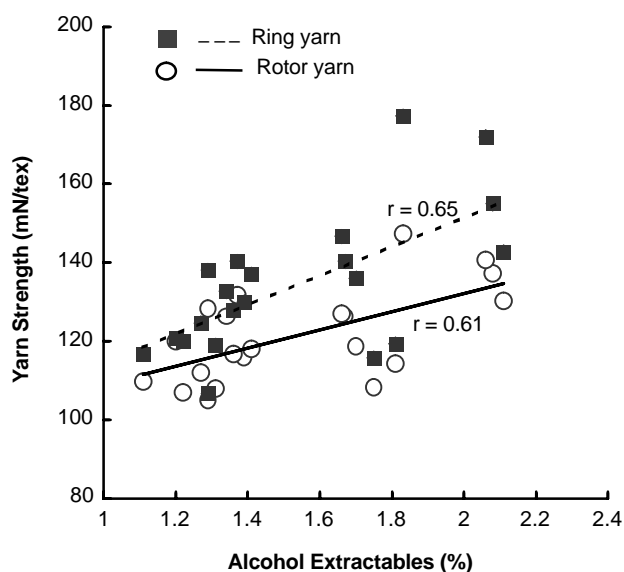


Figure 2. Relationship between ethyl alcohol extractables and single yarn strength.

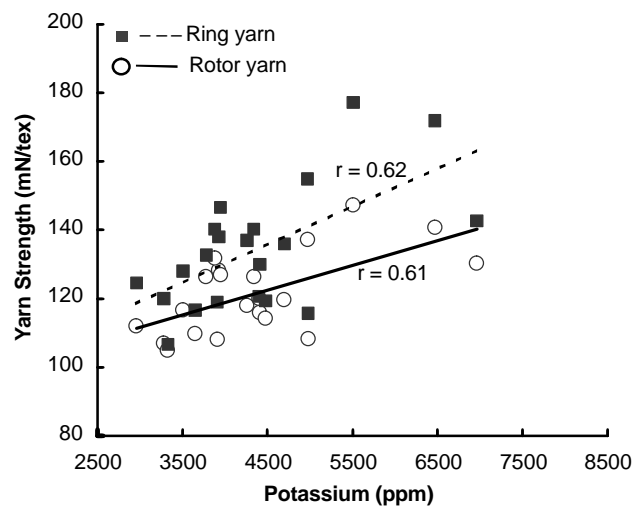


Figure 5. Relationship between the fiber potassium content and single yarn strength.

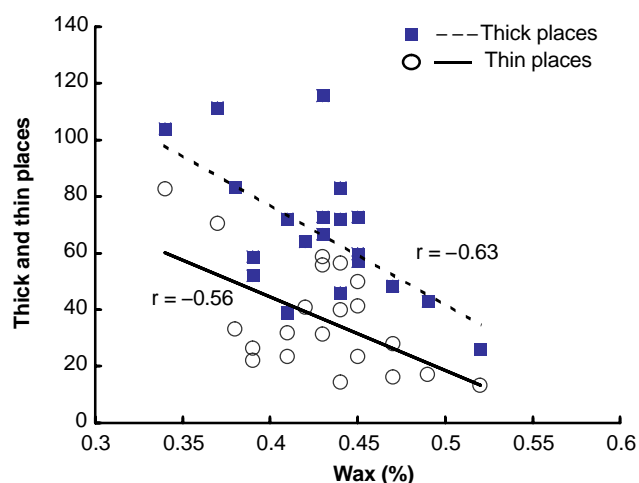


Figure 3. Relationship between wax content and rotor spun evenness thick and thin places.

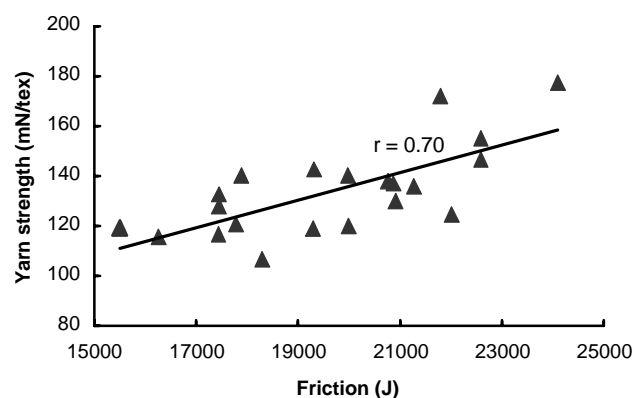


Figure 6. Relationship between fiber-to-fiber RotorRing friction and Ring spun single yarn strength.

Table 8. Correlation coefficients between fiber light metal contents and RotorRing friction, and yarn spin performance data.

	Skein				Single Yarn		Uster					
	Break Factor		Elongation		Strength		Thick Places		Thin Places		Neps	
	Rotor	Ring	Rotor	Ring	Rotor	Ring	Rotor	Ring	Rotor	Ring	Rotor	Ring
Potassium (K)												
Individual samples ($n = 21$)	0.60	0.63	0.52	0.42	0.61	0.62	-0.52	-0.41	-0.52	-0.43	-0.07	0.54
Area of growth ($n = 5$)	0.89	0.89	0.44	0.16	0.91	0.88	-0.62	-0.62	-0.61	-0.67	-0.51	0.80
Calcium (Ca)												
Individual samples ($n = 21$)	0.01	-0.12	0.11	-0.06	-0.01	-0.14	-0.12	0.38	-0.20	0.40	-0.08	0.35
Area of growth ($n = 5$)	-0.24	-0.37	0.55	0.29	-0.30	-0.37	-0.06	0.66	-0.20	0.64	-0.69	0.33
Magnesium (Mg)												
Individual samples ($n = 21$)	0.51	0.48	0.50	0.36	0.52	0.47	-0.39	-0.34	-0.37	-0.31	-0.19	0.36
Area of growth ($n = 5$)	0.74	0.75	0.61	0.52	0.77	0.72	-0.44	-0.54	-0.51	-0.58	-0.67	0.80
K + Ca + Mg												
Individual samples ($n = 21$)	0.60	0.61	0.51	0.39	0.61	0.59	-0.52	-0.35	-0.54	-0.35	-0.11	0.56
Area of growth ($n = 5$)	0.85	0.84	0.56	0.25	0.87	0.83	-0.63	-0.51	-0.65	-0.56	-0.67	0.88
Fiber-to-metal friction												
Individual samples ($n = 21$)	0.39	0.31	-0.03	-0.36	0.36	0.33	-0.46	-0.01	-0.48	-0.14	-0.34	0.36
Area of growth ($n = 5$)	0.61	0.48	0.68	-0.03	0.55	0.48	-0.74	0.12	-0.77	0.04	-0.89	0.94
Fiber-to-fiber friction												
Individual samples ($n = 21$)	0.61	0.66	0.01	0.10	0.53	0.70	-0.34	-0.55	-0.39	-0.60	-0.55	-0.08
Area of growth ($n = 5$)	0.90	0.95	0.22	0.17	0.93	0.95	-0.50	-0.87	-0.50	-0.91	-0.11	0.49

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